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ABSTRACT

The report presents a brief summary of the development and application of a taxonomy of undergraduate pilot training (UPT) tasks and skills. A surface analysis format based on cues, mental actions, and motor actions was developed which described flying tasks in terms of the sequential elements within each task. A set of classification rules was developed which utilized the descriptive analytical information generated by the surface analysis to identify the skills needed to execute the flying tasks described. A coding and matrix system was devised which made the classification system easy to use. The resulting taxonomic data system was applied to the solution of several representative flying training research problems. (Author)

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BEHAVIORAL TAXONOMY OF UNDERGRADUATE PILOT TRAINING TASKS AND SKILLS:
EXECUTIVE SUMMARY

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This technical report has been reviewed and is approved.

WILLIAM V. HAGIN, Technical Director
Flying Training Division

Approved for publication.

HAROLD E. FISCHER, Colonel, USAF
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report summarizes the development and application of a behavioral taxonomy of undergraduate pilot training (UPT) tasks and skills. The taxonomy specifies the fundamental flying abilities which comprise the training objectives of UPT. Its purpose is to provide a broadly applicable conception of UPT that obviates the need to continually study each specific training task or aircraft to determine the requirements for training hardware and software in research on and the development of optimized flying training programs.

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SUMMARY

This report presents a brief summary of the development and application of a taxonomy of undergraduate pilot training (UPT) tasks and skills. A surface analysis format based on cues, mental actions, and motor actions was developed which described flying tasks in terms of the sequential elements within each task. A set of classification rules was developed which utilized the descriptive analytical information generated by the surface analysis to identify the skills needed to execute the flying tasks described. A coding and matrix system was devised which made the classification system easy to use. The resulting taxonomic data system was applied to the solution of several representative flying training research problems.

PREFACE

This report summarizes a portion of the research being accomplished in support of Project 1123, Flying Training Development under the direction of Dr. William V. Hagin. The study was documented under Task 112302, Instructional Innovations in USAF Flying Training, Mr. Gary B. Reid, Task Scientist, and work unit 11230217, A Behavioral Taxonomy of Undergraduate Pilot Training, Dr. Edward E. Eddowes, Contract Monitor. Capt. Jack A. Thorpe assisted in editing this summary of the task and skill taxonomy development effort.

The research reported herein was conducted under the provisions of contract F41609-73-C-0040 by Design Plus, St. Louis, Mo., Mr. Robert P. Meyer, Principal Investigator. This effort covered the period between July 1973 and September 1974.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

INTRODUCTION

The Air Force's undergraduate pilot training (UPT) program is the keystone of USAF pilot training. This flying training program has evolved along traditional lines through many years of trial and error, rather than as the result of the application of an analysis and design effort. The purpose of this study was to analyze and specify the fundamental flying abilities which comprise the training objectives of UPT and to develop a broadly applicable conception of UPT that can be used to determine objectively the requirements for training hardware and software in research on and development of optimized flying training programs.

While a number of analyses of flying tasks have been accomplished in the past to identify the pilot's behavioral requirements, none of them proved suitable for application in the development of a taxonomic structure such as was generated by the present research. In this study, the results of such task analysis efforts were reviewed and revised to produce a surface task analysis format which described a pilot's aircraft control behavior. Subsequently, the skill required to accomplish this behavior was identified by applying classification rules and procedures which evolved during the study.

As soon as the pilot's tasks were defined and his required skills identified, a taxonomic organization was formulated to establish the relationship between flying training tasks and skills. The development of the behavioral taxonomy of UPT tasks and skills permits future research in flying training to focus on fundamental flying abilities rather than on training maneuvers and, as a result, this research may be expected to be more efficient and economical in producing data to support recommendations for improved flying training.

The present report summarizes the development and application of a taxonomy of UPT tasks and skills. A surface task analysis based on cues, mental actions, and motor actions was generated which described flying training tasks in terms of their sequential elements. A set of classification rules was developed which utilized the descriptive analytical information contained in the surface analysis. A simplified coding and matrix system was devised which made the task/skill classification scheme easy to use. The system made possible detailed analysis and taxonomic applications which can make an impact on future flying training research programs.

This taxonomic structure provided a tool of sufficient depth and flexibility to cover a number of the prime areas of research interest for the AFHRL Flying Training Division. Using the taxonomy has led to the identification of areas of redundancy and commonality within the present UPT program. Further, the taxonomy provides the means for evaluating the effectiveness of future modifications of the UPT syllabus and training methods. In addition, tasks generated to fill new training requirements can be supported by data generated through the use of the taxonomy.

The present report emphasizes the essential features of the task and skill taxonomy. The reader may consult the abstracts and summaries of the interim reports identified in the list of references for additional information on areas of specific interest.

SURFACE TASK ANALYSIS

A surface task analysis was defined as: An investigative process that lists behavioral flying tasks in sufficient detail, in accordance with established ground rules, to be utilized as a tool for classifying those tasks into specific flying training categories. The purpose of the surface analysis was to provide flexible, yet discrete behavioral descriptions for classifying flying tasks, where task is defined as: A group of related work elements performed in close temporal proximity and directed toward the accomplishment of a definable work goal. The descriptions of flying tasks provided by the surface analysis permitted identification of the skills needed for the performance of these tasks. To structure the surface analysis, a simple model of the flying process was constructed (Figure 1). The human element in the model is represented by the assimilation of Cues, and the resulting processes of Mental and Motor Actions, where: Cues (C) represent the environmental and system stimuli which excited the sensory systems of the human body, Mental Actions (ME) represent the cognitive processes initiated by perceived stimulus cues, preceding motor actions, and Motor Actions (MO) represent the physical actions resulting in movement of aircraft controls. This sequence of Cues - Mental Action - Motor Action (C-ME-MO) appeared to be a reasonable format for analyzing tasks and was adopted throughout the surface task analysis.

The main theme of the analysis was that flying tasks can be categorized into three types of transitional tasks: fundamental (F), composite (Cp) and continuous (Ct). Table 1 defines each of these transitional tasks and identifies the specific flying tasks in each of the categories. The surface analysis of these tasks was approached by applying these three rules:

1. Each event in a task can be broken down into elements consisting of a C-ME-MO sequence. This sequence permitted a simple homogeneous categorizing of tasks. The number of elements has no specific bearing on task difficulty, nor is there any particular correlation with a time base intended. However, the format does permit a continuity sequencing system.

2. Each task contains a short situation description to set the steady-state (dynamic aircraft forces are trimmed to allow essentially "hands off" flight) from which the transition (a change from one steady-state to another) is to begin. A goal is noted toward which the transition or transitions progress.

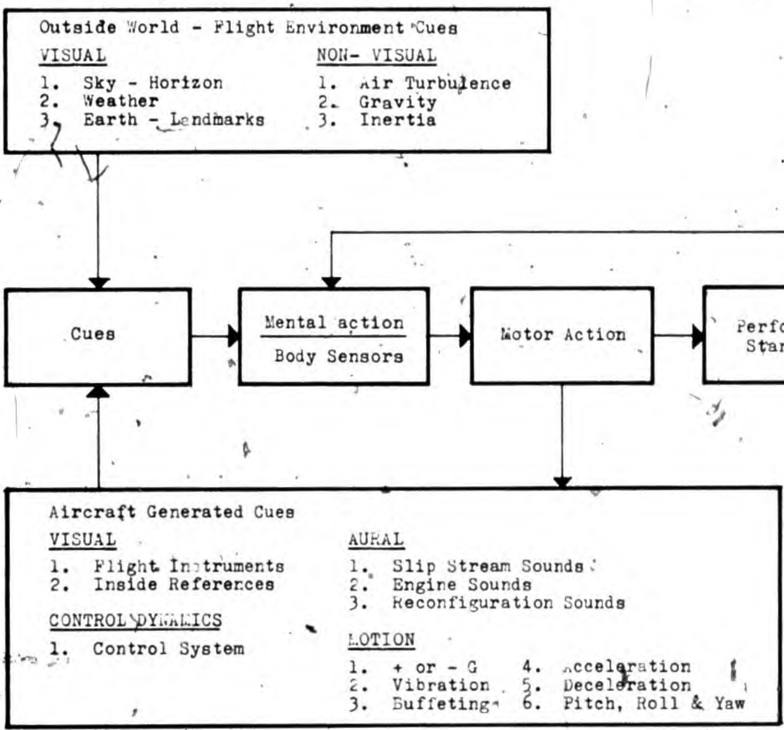


Figure 1. Pilot-Aircraft Paradigm

3. The aircraft considered was pure jet with retractable landing gear, flaps, and a full complement of flight instruments.

Table 2 shows the surface analysis of the first C-ME-MO sequence of a 360° overhead landing, a composite task. The full analysis contained twenty-three C-ME-MO sequences in all. From the descriptions of Cues, Mental Actions, and Motor Actions, a coded card was prepared that later became the major clerical tool for organizing and manipulating the full taxonomy. The format and codes used on this card are shown in Table 2, and are explained in detail in AFHRL-TR-74-33 (IV). For all tasks analyzed, and each sequence in each task, the same type of verbal descriptions were written as shown in Table 2, and the same type of card was generated to use in the taxonomy development.

Table 1. Flying Task Characteristics

A. Fundamental Transitional Tasks - The twelve control segments derived from the four steady-state flight paths, Straight-and-Level (St & L), Turn (T), Climb (C), and Descent (D):

1. St & L → T	7. C → St & L
2. St & L → C	8. C → T
3. St & L → D	9. C → D
4. T → St & L	10. D → St & L
5. T → C	11. D → T
6. T → D	12. D → C

The Fundamental Transitional Task is the smallest task part.

B. Composite Transitional Tasks - Two or more fundamental transitional tasks combined to perform a more complex flying requirement. The following are examples of Composite Tasks:

1. Take-Offs
2. Climb-Outs
3. Approaches
4. Landings
5. Chandelles
6. Lazy-8's
7. Slow Flight
8. Stalls
9. All X-Country Flying

C. Continuous Transitional Tasks - Any number of fundamental and composite tasks combined in rapid succession to complete a complex flight requirement. Continuous Transitional Tasks are divided into Primary and Advanced tasks. The following are examples:

Primary	Advanced
1. Loops	1. Clover Leafs
2. Barrel Rolls	2. Cuban 8's
3. Aileron Rolls	3. Immelmans

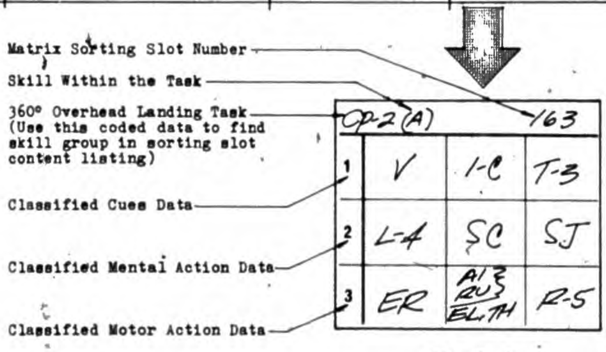
Table 2. Example of Surface Analysis and Coding System

SITUATION Aircraft at initial approach speed, level and maintaining ground track over centerline

TASK NO. Cp-2 TASK 360° overhead landing

TASK GOAL Land aircraft DATE Oct., 1973

EL. SEQ.	CUES	MENTAL ACTION	MOTOR ACTION
(A) 1.	BEGINS PITCH OUT Visual-Pitch att: cruise Bank att: level Outside ref, approaching pitch out point Aural-Normal envir. sound Control-Neutral pressure Motion-Normal G		Cp-2(A) 163 1 V 1-C T-3 2 L-4 SC SJ 3 ER AI RU EL,TH R-5
2.		Observes pitch out point	
3.			Coordinates aileron & rudder, moves elevator, adjusts throttle



File Card

TAXONOMY DEVELOPMENT

The taxonomy established a complete coding and notation system for the surface analysis and its elements. The taxonomy was defined as:

A manner of classifying and the rules and principles concerned with classification, of the behavioral elements found in the skills described in the surface analysis in such a way that a useful relationship could be established among them.

Further, a basic skill was defined as the behavioral elements that are required to perform each task sequence.

The taxonomy extracted, by the application of simple rules, those behavioral elements which were required for the performance of flying tasks. The rules were developed specifically for this application after careful examination of many behavioral classification categories developed by previous researchers.

Taxonomy Format - The initial division in the classification methodology followed the surface analysis structure and identified the parts of a skill in terms of a Cue, Mental Action, or Motor Action segment. Each of these segments was further subdivided into specific behavioral elements and descriptors. Table 3 shows the final form of the categories available for each part of a skill determined through many iterations. Each rule is also briefly discussed by segment.

Taxonomy Validation - Once the verbal descriptions of the C-ME-MO sequences of the surface task analysis were prepared and the classification rules shown in Table 3 had been tested and refined, a validation study was performed to see if these rules could be used effectively by training research personnel who had not previously been involved in the taxonomy development project. The validation study determined how well the taxonomy could classify the skills derived from the surface analysis and indicated that the taxonomy system was both effective and usable.

The individual UPT maneuver analysis kits consisting of instructions, classification rules, a short sample task analysis and two other task analyses to be classified, were presented to USAF subjects. As shown in Figure 2, a three-column format was adopted in order to present as much pertinent information to the evaluator as possible and show graphically the relationship between the classification instructions, the surface analysis and the behavioral element categories.

Table 3. Behavioral Element Categories and Classification Rules

1. CUES			
KIND	COMPLEXITY	TOTAL INPUTS	
Visual.........V	1-Cue........1-C	T-1	T-5
Aural..........A	2-Cues.......2-C	T-2	T-6
Control........C	3-Cues.......3-C	T-3	T-7
Motion.........M	4-Cues.......4-C	T-4	T-8...etc.

2. MENTAL ACTION		
COMPLEXITY	INFORMATION PROCESSING	DECISION PROCESSING
1st. Level....L-1	Specific Cue Processing....SC	Simple Judgement......SJ
2nd. Level....L-2	Memory Recall Processing....RP	
3rd. Level....L-3	Multi-Cue Processing....MC	Complex Judgement......CJ
4th. Level....L-4	Iterative Processing....IP	

3. MOTOR ACTION		
CONTINUITY	CONTROL OUTPUT	COMPLEXITY
Establish Attitude.....EA	Aileron..........AI	1st. Rank.......R-1
	Elevator.........EL	2nd. Rank.......R-2
	Rudder...........RU	
Establish Rate of Attitude Change.......ER	Throttle.........TH	3rd. Rank.......R-3
	Trim.............TR	4th. Rank.......R-4
	Other Outputs....OO Speed Brakes - Gear Wheel Brakes - Flaps	5th. Rank.......R-5

Rules for Cue Classification

1. Identify all of the different kinds of cues used in the task sequence.

2. Determine the complexity of the cues. Complexity is determined by counting the different kinds of cues.

3. Determine the total number of cue inputs. This total is determined by totaling the number of individual cues found within each of the cues.

Rules for Mental Action Classification

1. Determine the complexity of the mental action involved. Complexity is determined by noting the number of kinds of cues as found in the cues rule No. 2 above (Complexity), counting the number of different control and discrete actions in the motor action column of the task sequence, and identifying the proper category from the following combinations:

One Cue	-	Zero or one control action
One or more Cues	-	Non-coordinated control actions
One or more Cues	-	Coordinated control actions
Two or more Cues	-	Both coordinated and non-coordinated control actions

2. Select the appropriate information processing category. Compare the action verb used by the analyst in the mental action column of the task sequence with these definitions:

Specific Cue Processing	-	Observes
Memory Recall Processing	-	Anticipates
Multi-Cue Processing	-	Determines
Iterative Processing	-	Sustains

3. Determine if the mental action entry requires a simple judgment or a complex judgment.

A decision based on a specific cue, fact, or procedure is a simple judgment.

A decision based on estimation or interpretation is a complex judgment.

Rules for Motor Action Classification

1. Decide if the motor action results in the establishment of a stable attitude or produces a rate of attitude change.

2. Identify all control outputs made by the pilot in this task sequence.

3. Indicate the complexity of the motor actions taken by the pilot. Complexity is determined by selecting the appropriate complexity rank from the following list:

1st Rank	-	One output
2nd Rank	-	Non-coordinated outputs
3rd Rank	-	Two coordinated outputs
4th Rank	-	Three coordinated outputs
5th Rank	-	Coordinated and non-coordinated outputs

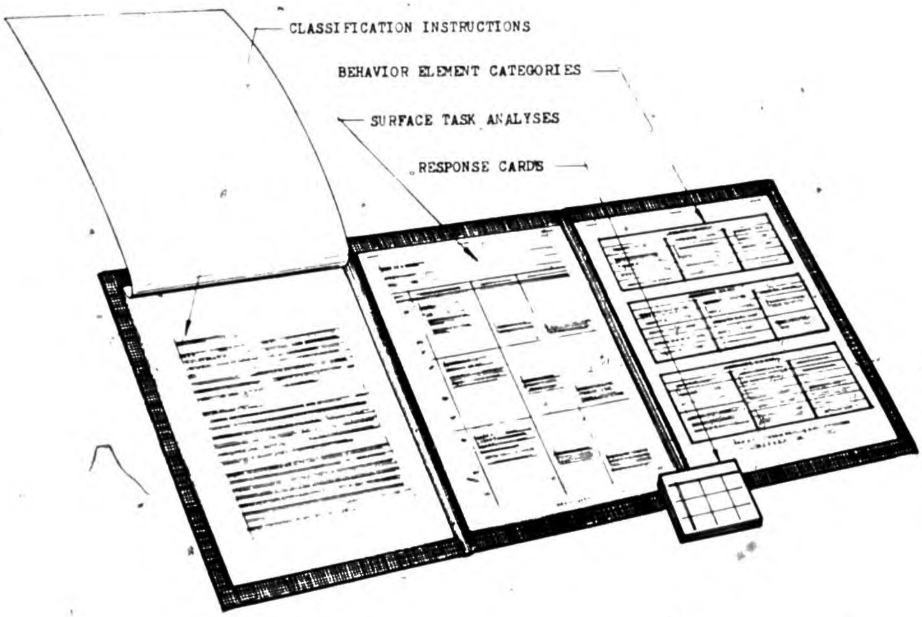


Figure 2. Maneuver Analysis Kit

The maneuver analysis kit was ultimately used successfully to:

1. Evaluate response of subjects in terms of consistency and determine areas of misunderstanding and ambiguity in the taxonomy components.

2. Evaluate the workability of the proposed coding system and response method in actual practice.

3. Produce an organized taxonomy classification kit which would be used by researchers to classify tasks during the project.

The classification by the nine subjects who completed the study formed the basis for the data analysis. These nine test subjects all were knowledgeable in the area of flying training. A percentage of agreement was computed among subjects for each individual classification rule. Based on this agreement criterion, an overall agreement of 82% on both tasks was found. Figure 3 shows the agreement levels for the individual classification rules.

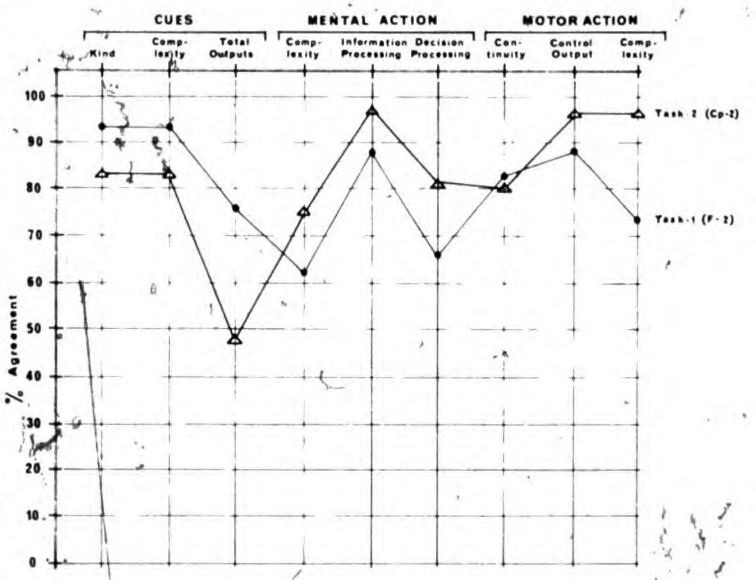


Figure 3. Validation Agreement Level

The overall high agreement among subject's classifications indicated that personnel not specifically trained in the use of the taxonomy could effectively and successfully apply the taxonomy. All subjects entered the study naive and required only a few minutes of instructional preparation. A knowledgeable non-pilot showed no scoring differences, indicating that only flying term familiarity was a prerequisite for taxonomy utilization.

Taxonomy Summary - The use of the classification system was shown not only to be possible, but could be executed by personnel only familiar with flying vocabulary. There was no requirement for skilled professionals familiar with taxonomies to accomplish classification tasks. The high overall agreement among subjects in skill classification not only helped validate the system, but also showed the surface analysis to be a useful research tool. Further, similar trends were noted in all tasks (i.e., visual and instrument) indicating internal consistency of the classification scheme.

TAXONOMY SYSTEM OPERATION

The surface task analysis and classification rules then were integrated to provide an effective tool for those involved in flying training research. The system was developed and organized so that it is usable without specialized training. The taxonomy is composed of six basic cross referenced data areas shown in Figure 4.

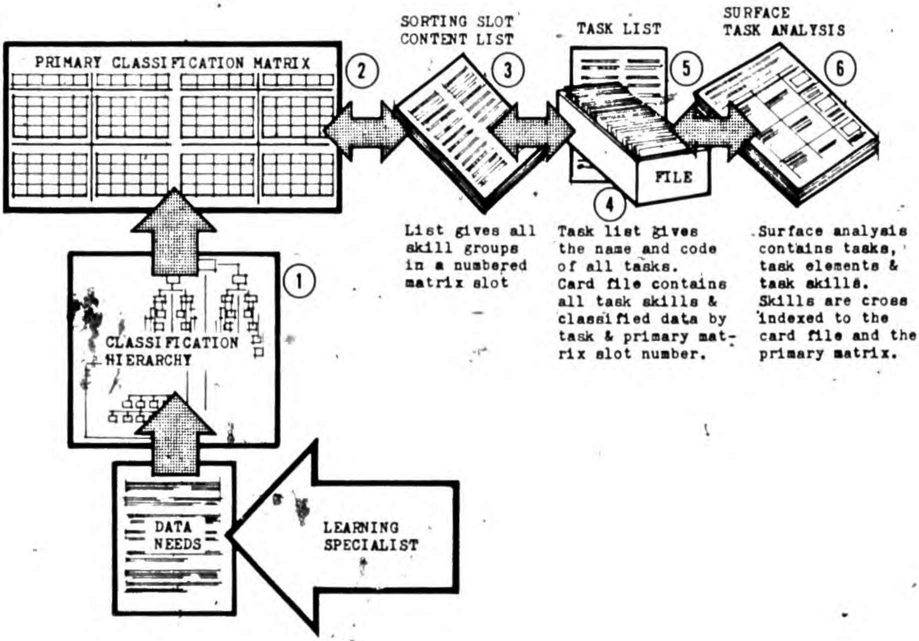


Figure 4. Taxonomy Data System

1. Classification Hierarchy - This was the basic organizational structure used in categorizing all tasks and skills within the taxonomy. It was directly related to the nine rules used to classify all tasks in the surface analysis. The hierarchy shows at what specific levels data from each of the nine rules can be found.

2. Classification Matrix - The classification matrix was the primary device used in sorting all flying skills into basic skill groups. Consequently, it also became the focal point of the taxonomy as a useful tool. The

matrix, composed of eight sub-blocks, allowed the final sorting of skills into basic skill groups with the order shown in the classification hierarchy. The original research matrix was a four by eight foot board and permitted a hands-on method of developing a useful system.

3. Sorting Slot Content List - This list shows the tasks and skills in coded form and established the basic skill groups contained in each slot in the matrix sub-block.

4. Task List - This list translated the task codes into the task names related directly to the surface task analysis.

5. Card File - A skill card file was established to cross reference all skill information in the taxonomy data system. These skill cards were filed according to the order shown on the task list.

6. Surface Task Analysis - The surface analysis provided the task information upon which the taxonomy was built. Each task was made up of task sequences with the cues, mental action, and motor action (C-ME-MO) elements forming the substance of each sequence. Since the C-ME-MO elements were the building blocks for the basic skills of each task, reference to this information can be most important to researchers. For this reason, the skill data found on each file card is also found as a cross reference in each C-ME-MO sequence in the surface task analysis.

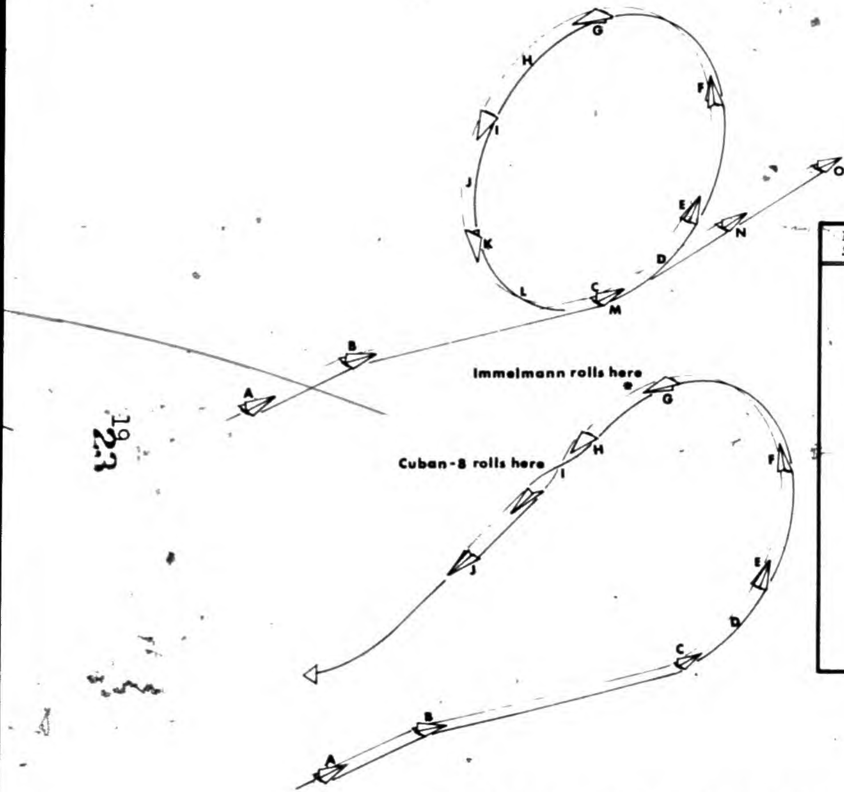
TAXONOMY APPLICATIONS

The end product of the taxonomy development and most important area of this research was the illustration of its application to flying training. The approach to taxonomy applications has been to determine where the introduction of such information would be beneficial in solving problems relating to flying training. Applications can focus on many different ways this taxonomy and the taxonomic data system may be used. However, any application may use any of the six areas of the system to assist in problem solution. Two applications to training are briefly discussed below to illustrate how the taxonomy may be used. Naturally, many other applications are possible based on user requirements. In any such application, the taxonomy can provide a useful structure for problem solution.

Redundancy Analysis - The first example to be discussed compares skills between two or more flying tasks to determine redundancy on a one-to-one basis. Three tasks: the loop, Immelmann and Cuban 8 were compared. Figure 5 shows these maneuvers and their task sequences. This information was then restructured to list the basic skill group identifiers for each task. It was immediately evident that approximately the first half of these tasks are identical and that the other half have similar skill groups.

From this data, a determination of task training order can be made. In this case, the number of simple versus complex judgments and task lengths were compared. This analysis led to the recommendation of the following order: loop first, Immelmann second, and the Cuban 8 third. This information is important as the current UPT syllabus gives no training order for these tasks. Other uses of this data include redefinition of training emphasis due to the repetitive nature of these tasks, the elimination of tasks to reduce training time and the development of new training tasks to replace the old. An example of a new task is presented next.

Standard Flying Task - This example illustrates how the taxonomy can supply analysis to assist in the development of standard flying tasks with evaluation procedures to judge the effectiveness of proposed tasks. For the example, the approach to landing task was utilized.

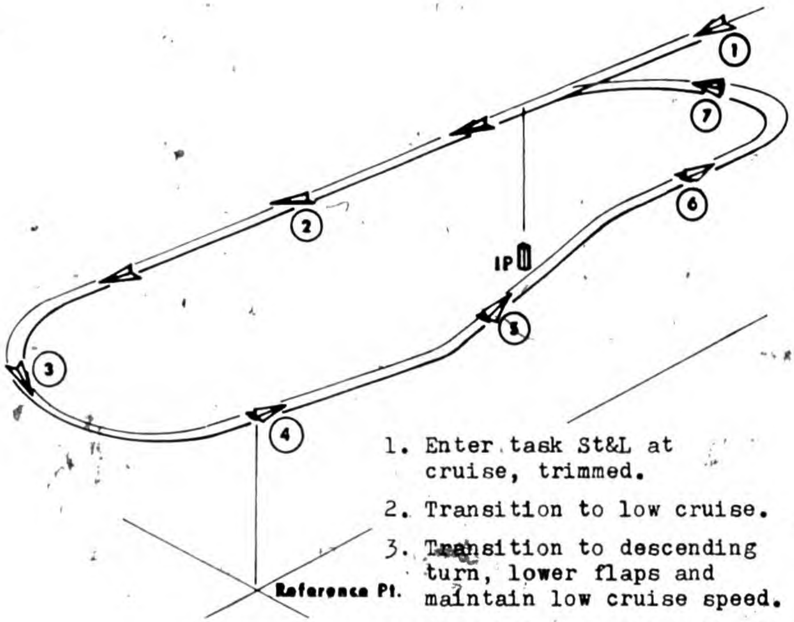


Element Sequence	Loop	Immelmann	Cuban 8	Comments
A	161•	161•	161•	
B	102	102	102	
C	66•	66•	66•	
D	126	126	126	
E	142	142	142	Identical
F	121	121	121	Sequence
G	141	141	141	
H	41•	141	125	
I	141	125	123	
J	144	142	165•	
K	45•	125	41•	
L	41•	122	142	
M	5•	27•	121	
N	32		141	
O			125	
P			123	Similar
Q			165•	Sequence
R			41•	
S			142	
T			22•	

• Indicates Simple Judgment Skills
___ Indicates like Skills

Figure 5. Loop, Immelmann and Cuban 8 Comparison

Based on a simple but detailed analysis, a new task was developed which incorporated the essential characteristics of the normal landing task elements. Further information can be found in the Phase III report AFHRL-TR-74-33 (IV) entitled: Behavioral Taxonomy of Undergraduate Pilot Training Tasks and Skills: Guidelines and Examples for Taxonomy Application in Flying Training Research. The end product was the landing training task (St-3) shown in Figure 6. This new task incorporated 79% of the landing skills and added pertinent go-around skills, making it an effective training task.



1. Enter task St&L at cruise, trimmed.
2. Transition to low cruise.
3. Transition to descending turn, lower flaps and maintain low cruise speed.
4. Transition to straight ahead descent at low cruise using outside reference line.
5. Transition to climb and raise flaps.
6. Transition to St&l flight trimmed for cruise.
7. Transition to turn.

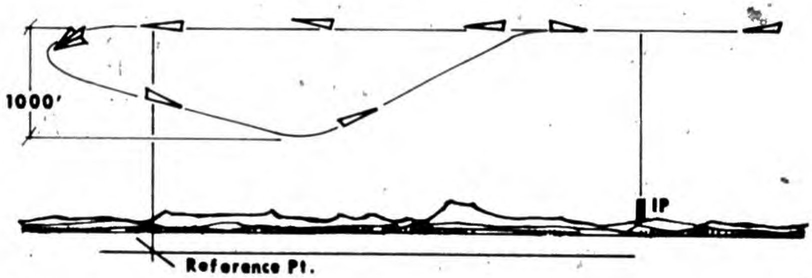


Figure 6. Landing Training Task

CONCLUSIONS

The taxonomy developed during this research is a unique tool which can be applied to all flying tasks. The application of taxonomic information in training research provides specific information on as well as increased insight in understanding basic flying skill requirements. The taxonomy, thus, can have a direct influence in the development of present and future flying training research strategies.

The taxonomy, which reduced UPT tasks into basic skills, can be used to identify skills across a number of selected tasks or an entire training syllabus. It is also possible to analyze skills within tasks in terms of difficulty and redundancy. Basic skill groups have also been identified. This skill group information has been utilized effectively to develop standard training tasks, as well as specific training tasks. The logical structuring of such training tasks from objective skill analysis can produce a viable building block approach not found in the current UPT system.

This building block concept, through a progression from simple to complex tasks and skills, can produce improved efficiency and economy in terms of training time and energy utilization. Precise task requirements derived from a detailed skill analysis would reduce uncertainty for both the student and instructor. A concept such as this also lends itself to the increased use of simulation in flying training in areas other than instrument instruction. Training tasks, done to acquire skills needed to accomplish a specific task, would provide a logical placement of simulation within a flying training program.

A new training strategy based on a skill taxonomy which emphasizes the role of simulation is a near term reality. The concept, once established, would provide the kind of flexibility needed to accommodate any future training requirements.

REFERENCES

The documents identified below describe the results of the three phases of the development of a behavioral taxonomy of UPT tasks and skills summarized in this report.

Meyer, R.P., Laveson, J.I., Weissman, N.S. and Eddowes, E.E. Behavioral Taxonomy of Undergraduate Pilot Training Tasks and Skills: Surface Task Analysis, Taxonomy Structure, Classification Rules and Validation Plan, AFHRL-TR-74-33 (II), Air Force Human Resources Laboratory, Williams Air Force Base, Arizona, October, 1973. AD-A000 053.

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Meyer, R.P., Laveson, J.I., Weissman, N.S. and Eddowes, E.E. Behavioral Taxonomy of Undergraduate Pilot Training Tasks and Skills: Guidelines and Examples for Taxonomy Application in Flying Training Research, AFHRL-TR-74-33 (IV), Air Force Human Resources Laboratory, Williams Air Force Base, Arizona, December 1974.